Title: Modeling the Bergeron-Findeisen process using PDF methods with an explicit representation of mixing

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Abstract:

Currently, the accurate prediction of cloud droplet and crystal number concentration in cloud resolving, numerical weather prediction and climate models is a formidable challenge. The Bergeron-Findeisen process in which ice crystals grow by vapor deposition at the expense of super-cooled droplets is expected to be inhomogeneous in nature—some droplets will evaporate completely in centimeter-scale filaments of sub-saturated air during turbulent mixing while others remain unchanged [Baker et al., QJRMS, 1980]—and is unresolved at even cloud-resolving scales. Despite the large body of observational evidence in support of the inhomogeneous mixing process affecting cloud droplet number [most recently, Brenguier et al., JAS, 2000], it is poorly understood and has yet to be parameterized and incorporated into a numerical model.

In this talk, we investigate the Bergeron-Findeisen process using a new approach based on simulations of the probability density function (PDF) of relative humidity during turbulent mixing. PDF methods offer a key advantage over Eulerian (spatial) models of cloud mixing and evaporation: the low probability (cm-scale) filaments of entrained air are explicitly resolved (in probability space) during the mixing event even though their spatial shape, size and location remain unknown.

Our PDF approach reveals the following features of the inhomogeneous mixing process during the isobaric turbulent mixing of two parcels containing super-cooled water and ice, respectively:

1. The scavenging of super-cooled droplets is inhomogeneous in nature; some droplets evaporate completely at early times while others remain unchanged.

2. The degree of total droplet evaporation during the initial mixing period depends linearly on the mixing fractions of the two parcels and logarithmically on Damköhler number (Da)—the ratio of turbulent to evaporative time-scales.

3. Our simulations predict that the PDF of Lagrangian (time-integrated) subsaturation (S) goes as S^{-1} at high Da. This behavior results from a Gaussian mixing closure and requires observational validation.